SOLAR PHYSICS[1]

III.

YOU will recollect that in my last lecture I explained to you the special absorptions that were due to certain hydro-carbons. To-day I wish to tell you some of the applications that can be made from an investigation and examination of this series. Before I proceed farther I wish to show you not only that there are absorptions which are due to the vibration of the atoms of these hydro-carbon molecules, but also that there is a general absorption which seems due to the molecular vibration of these same hydro-carbons.

I wish to point out to you the general absorptions of the first three of those spectra, the alcohol series. The first one is methyl alochol which has a light molecule, or rather, I may say that it is lighter than the molecule of the next, common alcohol which in its turn again is lighter than propyl alcohol. You will see that the general absorption creeps up from the ultra-red towards the red. In each case the lighter the molecule the more vigorous is the general absorption. I was obliged to refer to this, because through the course of my lecture you will see that this has an important bearing on some of the results which we got.

Another point is the effect of heat upon this general absorption; and here I speak with a certain amount of diffidence. My belief is that the general absorption is increased by an increase of temperature in the hydro-carbons, in water, or in any of those liquids which we examined. Thus, with water, we find that the general absorption creeps up, the hotter the water is. In fact, at this time of the year when the temperature is high, it is very hard indeed to get some of those special absorptions very far down in the ultra-red, because they are blocked out, as it were, by the general absorption which is due to the vibrating molecules—molecules of course vibrating in the manner which I have described.

The hydro-carbons which we have examined were all in the liquid state, and it seems very probable—nay, more than probable—almost certain,—that if you were to convert those liquid hydro-carbons into gas you would get their absorptions in the same localities. For instance, in the diagram (Fig. 14) I will show you the absorption spectrum of bromine. The top spectrum is the absorption spectrum of liquid bromine, and the bottom spectrum is the spectrum of gaseous bromine. You will see that the difference between the two is that, where you have the general absorption in the liquid, it is split up into lines in the case of the vapour. Thus in the case of the liquid we have the blue end of the spectrum entirely cut off by a general absorption gradually increasing from the blue to the green. When we pass to the gaseous bromine we have the same absorption but terminated with bands. I do not say that this is always the case in bodies which have the same chemical constituents.

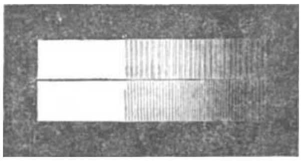

FIG. 14.—Absorption spectra of liquid and gaseous bromine.

Now, so far having cleared the ground for our next point, I must refer you back to the map of the infra-red of the solar spectrum which I alluded to last time. After we had completed our map of the ultra-red absorption spectra of these different hydro-carbons, we had the curiosity to look at the map of the solar spectrum to see whether we could discover anything at all in relation between the two. Col. Festing and myself were very surprised to find that we had mapped lines identical with lines in the ultra-red region of the solar spectrum. Thus, for instance, when we looked at the spectrum of water—we found that one line lay in the little *a* group, and had a wave length of 833. When we examined chloroform, we also found that it had a great many lines which we suspect are to be found in the solar spectrum. We then went to ethyl iodide, and here we also found coincidences; but the coincidences were more marked than in the former case. For instance, last time I told you that, in order to identify the base or radical band of any particular hydro-carbon, it was necessary to look for the base or radical, and, if need be, to confirm it by looking at other bands which were situated somewhere about the little *a* in the solar spectrum. In the case of ethyl iodide we found that the band about little *a* coincided with part of the band in the solar spectrum. We also found that all of the alcohol series had one strong line coincident with a solar line; other lines were also to be found coincident with other lines of the solar spectrum. Furthermore the relative intensities of the lines in the liquid and solar absorption spectra seemed identical.

What, then, was the conclusion which we had to draw from this? It was that the lines in the solar spectrum must have something to do, or must have some connection at all events, with the lines found in the hydro-carbon series.

Now, as I have said, where you have a liquid you need not expect the spectrum to be so minutely covered with lines as you would if you had the body in the gaseous state, and, in all probability, suppose that we could have ethyl iodide in a gaseous state which is a thing not impossible to have—(it is very easy, only it is difficult to get enough of it)—those radical bands would probably split up into fine lines, and from the preliminary experiments which we have made it seems as if that would really be the case. But as this of course is a work of only a few months old, this requires confirmation; and Col. Festing and myself propose to carry out with vapour what we have already carried out with liquids. In our own minds there is no doubt that some at least of the hydro-carbons we have examined, are to be found in the solar spectrum, and we are also inclined to think that the hydro-carbons are not combined with oxygen, because, were they combined with oxygen, we should expect to find a more complicated spectrum of these particular lines or bands in the solar spectrum.

Now suppose that we have such a compound as an ethyl compound of some description in the solar spectrum. Where can such a compound exist? It must exist in one of two places: It must exist near the sun, or it must exist in our own atmosphere. Now the nearer you go to the sun of course the hotter the region, and it is quite impossible that these hydro-carbons, whatever they may be, should exist very near to the solar disc or to the nucleus. But if they do exist in the solar atmosphere at all they must exist at some little distance from them in a cooler region. You will recollect that Mr. Lockyer pointed out very clearly that there are regions around the solar nucleus which have vastly different temperatures.

Now the question is, what compounds could exist even at a comparatively low temperature. There is a gaseous body allied to the ethyl series which would have the same radical or base bands, namely, acetylene. Acetylene can exist at a high temperature; it has been found in the cooler part of the arc of the electric light, but we also know that three of its molecules will combine to form benzine. Let us see what we should get, suppose that we have a ring of this hydro-carbon outside the sun; and then let us see what evidence would prove the presence of this hydro-carbon. I have here a small diagram showing what we might expect to see. The black disc is supposed to be the solar nucleus, and this black ring which you see round it is supposed to be the ring of a hydro-carbon. The slit of the spectroscope is also shown. Now, if it exists at some little distance from the solar nucleus, you will see that when the light passes from the edge of the sun through that ring and then through the slit of the spectroscope, it will pass through a deeper layer of matter than it would supposing the light came from the centre. In some photographs I took of the solar spectrum some time ago, before we made these experiments, I found that some of the lines were more broadened at the limb of the sun than were other lines; and these lines apparently are coincident with these hydro-carbon lines. So, you see, from an examination of the hydro-carbons and an exam-

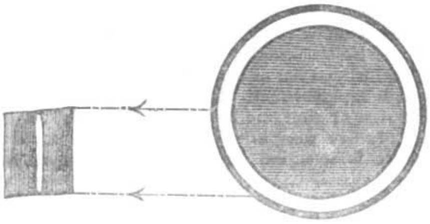

FIG. 15.—Solar disc surrounded with a hydrocarbon ring.

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[1] Lecture delivered on May 25, 1881, at the Lecture Theatre, South Kensington Museum, by Capt. Abney, R.E., F.R.S. Continued from p. 191.

ination of the sun's limb, we may be able to form an idea as to whether such hydro-carbons are present in the atmosphere of the sun. Of course, as I said before, this work is new and will require a great deal of confirmation before it can be put forward as an absolute certainty. Mr. Lockyer suggested another way in which this broadening of the lines of the limb might arise. Supposing the corona were to be composed of hydro-carbon, and also supposing, we got a streamlet or streamer of the corona lying in the same line to the earth as the limb of the sun; then we should get exactly the same result. Studying the diagrams, it is quite evident that if it were composed of hydro-carbon we might get a thickening of the hydro-carbon lines at the limb, because it would pass through a greater quantity of matter than at the centre.

Secondly, these hydro-carbons might exist in our atmosphere; but then if they did exist there, there is a very easy way of proving whether such is the case. If we photograph the solar spectrum when the sun is very high in the heavens, and photograph it also when the sun is very low, we pass through a very much larger quantity of atmosphere in the second case than we do in the first case. Now I have never noticed that there has been any particular absorption with a low sun, except, it may be perhaps, a greater general absorption on the more refrangible side of the dark Z line. But this, of course, like the rest of the work, requires still further examination, and I am only, as it were, throwing out hints as to the work that will have to be done in this particular region.

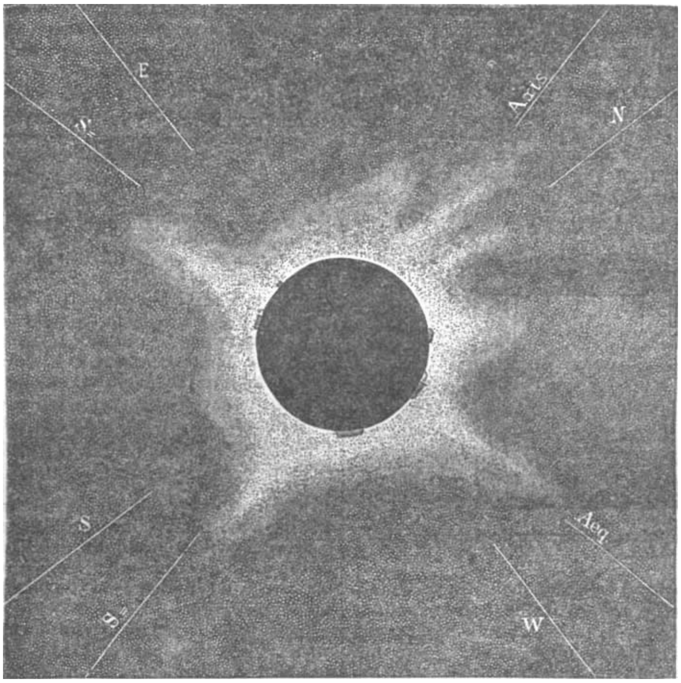

Fig. 16.—Solar corona, as seen during an eclipse.

But now about aqueous vapour. In 1860 Brewster and Gladstone published a map of the spectrum, showing atmospheric absorption, and this investigation was continued by an eminent French physicist, M. Janssen, in 1864. Brewster and Gladstone had shown that certain lines were due to atmospheric absorption; and Janssen went farther and tried to confirm their researches, or to correct them. He lit a bonfire near Geneva, and observed the spectrum of the bonfire thirteen miles off, and found that there were a great many lines in the spectrum when he observed it thirteen miles off, which were not present when he observed it near; and these could only be due to atmospheric absorption. But that did not settle the point whether the lines that he noticed were due to the air or to aqueous vapour. In order to ascertain which lines were due to aqueous vapour, in 1860, he filled an iron cylinder 330 feet long with steam, and then observed the absorption spectrum of steam through this great length of tube, and he noted that certain lines were visible in the spectrum which were also visible in the spectrum which he obtained by viewing the bonfire thirteen miles off. As a further confirmation, he appealed to the stars. He observed Sirius, for instance, at a high altitude, and also at a lower altitude, and found that there was a darkening of some of the Fraunhoferic lines. Whether this was due to aqueous vapour or to the air lines, of course could only be settled by reference to the absorption spectrum which he obtained from viewing a candle flame through the 330 feet of aqueous vapour. That distinguished man, Ångström also examined into the subject, and in his map are shown the lines which he considered to be due to the atmosphere.

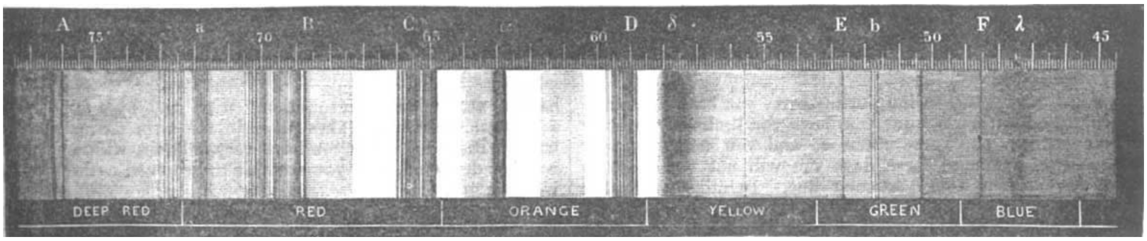

Fig. 17.—Angström's map, showing telluric lines.

Now from very careful examination, he considered that neither the A line nor the B line was due to aqueous vapour, but he thought they might be due to carbonic acid. From what we have observed, it seems highly probable that they are not due to carbonic acid because, if we had a compound of carbon and oxygen, we should not expect to see such a spectrum at all. I think that from the context we shall see a great probability as to what they may be due. Other observers observed the spectrum of the atmospheric lines, but perhaps the most recent and trustworthy observer is Prof. Piazzi Smyth. He published in the "Edinburgh Astronomical Observations," vol. xiv., a memoir regarding these black lines. Regarding B he says that they are merely dry air lines, and that the A line is a solar line. I should like to quote his own words with regard to this particular A line. He says, "The remarkable clearness, plainness, and strength of the lines composing A and its parallel bands in a high sun tend to claim the said A and its appendages a solar line, and, if so, it is a grander one by far than any other solar line in the whole of the solar spectrum. If, on the other hand, some observers will claim A as only a gas effect, Ångström has said that A grows or reinforces at sunset. I may say that I have seen it this summer (1877) in Edinburgh almost at the point of sunset, and ascertained with a more powerful prism, that, though heavily black as it was, it hardly was in reality grown at all." He says that the time was too short for him to measure absolutely the number of lines, but his impression was that the number of lines composing the A band was not diminished at all, and that the A line presents the same appearance at sunset as it did in a high sun.

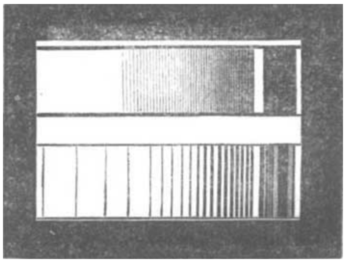

FIG. 18.—Top spectrum the A line; bottom spectrum the benzine radical band.

Now, as I said at the beginning of my lecture, we must take into consideration the general absorption which is always more or less visible in the spectrum, and at sunset we always have greater general absorption than we have of course when the sun is at midday, because the stratum of air between us and the sun is greater in the one case than it is in the other. Smyth, I believe, supposed that the A line was due to hydro-carbon, and I should like to show you that, probably, his surmise is correct. [I subsequently found that this idea did not originate with the Professor.] An examination will show you how very remarkably like the A group of lines is, to this B group of lines. They both have a band—a common band which, with a very high magnifying power, is splits up into fine lines. From analogy, one would suppose, then, that the A and B lines are due to the same substance. If one looks at the A line with a small dispersion, one sees it very much of the same form as the benzine radical band that you saw (Fig. 18). It appears to have a dark distinct band, and then to shade off for some considerable distance. Now the remarkable thing about this is that if I transferred this A line such as we see here to about a thousand wave lengths down the spectrum, we should get the characteristic radical band of benzine. In our comparison of the solar spectrum with that of benzine we have found unmistakable proofs of the existence of benzine in the solar atmosphere. This being the case, the big A line and the benzine, or the benzine series may have some connection one with the other; and it seems to me from analogy that sooner or later the A line will be found to be due to a hydro-carbon of some kind. You recollect in the photograph I showed you last time, that as the molecule got lighter the radical band went up towards the blue. Now the benzine has essentially a comparatively speaking heavy molecule. It is composed of 6 of hydrogen and 6 of carbon, and therefore if we can examine a hydro-carbon, which has the same proportions of hydrogen to carbon, but of a different molecular grouping, I think it extremely probable that eventually we shall find that the A line belongs to that particular group of the hydrocarbons in which there are equal atoms of hydrogen and carbon. As to the B line the question is, can the B line, which has a similar look to the A line be due to a hydro-carbon. That requires great consideration. Every observer, I believe, has put B down as an atmospheric line, and therefore if such be the case we shall have to look for a hydro-carbon high up in our atmosphere.

Now, to come back, what would be the effect of aqueous vapour? First of all, we should have a general absorption in the ultra red part of the spectrum, and then also a special absorption. The annexed diagram (Fig. 19) is from a photograph of the solar spectrum taken through various thicknesses of water, and you will see what kind of effect the various thicknesses have upon absorption

This bottom figure is the spectrum through three feet of water. The next part of the spectrum is photographed through one foot of water; and the next part of the spectrum is photographed through six inches of water. You will see what a remarkably little absorption there is of the visible spectrum due to a certain amount of water. Now, can water have the same effect as aqueous vapour? I think it can. If M. Janssen had condensed the steam in the 330 feet tube, and only had a thickness of somewhere about three inches of water to look through, then looking through three inches of water he would have seen no absorption whatever. In other words, where you have a liquid converted into a vapour a given weight of it seems to absorb a great deal more as vapour than it does as liquid. Sometimes we see this even in the visible part of the spectrum.

When you have a cold north-east wind, you have an atmosphere very free from moisture, and you are able to go down in the infra red regions very far; but when you have a change of weather and a south-west wind, for instance, you have a remarkable absorption setting in, and you have the limits of the solar spectrum ending somewhere about τ, and you may try your utmost and yet on one of these days you will not be able to go one jot farther than that particular line. In other words, the general absorption due to atmospheric water in some form or another comes in, and not special absorption.

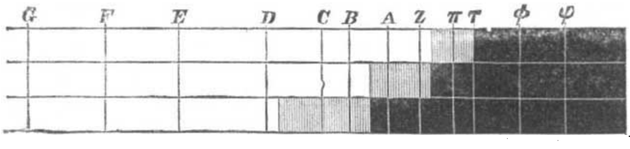

FIG. 19.—Absorption spectra of different thicknesses of water.

In the diagram, Fig. 7 (see p. 188), we have two bands, ϕ and ψ, at the extreme right of the ultra red, and only on two days in two years have I ever been able to obtain a photograph of those particular bands. They were obtained in both cases in March, and it was when the air was particularly free from aqueous vapours, and it was very cold. To sum up, where you have a west wind, or a south-west wind and high temperature, a general absorption takes place in the ultra part of the spectrum. It is only when you have very cold air, with a north-east wind or dry wind, that you are able to get even as far down as we have got.

The next point to which I wish to call your attention is, Is it probable that in the ultra red part of the spectrum we should ever be able to obtain evidences of metallic lines, or lines which are due to metallic vapours? I think that it is highly improbable that we shall. The few metals that we have tried have given almost a negative result except in one or two cases. Thus in looking through the list of lines due to the metallic elements, there are very few that go even as far as 700 in the scale of wave-lengths.

They generally end somewhere about 650 wave lengths. Of course there is one well known exception, which is the potassium line, which has the wave-length of 770 (in fact below the A line), and is visible with a certain amount of difficulty. But as a rule all the bright metallic lines end above 700, and when they get towards 700 they are always thin lines and poor lines. When you come to think of it, it seems highly improbable that you should obtain lines very low down except in the case of metals of low fusing point. If you have a metal of low fusing point, of course it is much more likely that you get lines of low refrangibility than you would if the metals have a high fusing point, and as a fact, taking a metal which has got a high fusing point such as iron, you find no line in the ultra-red part of the spectrum, whereas in the case of sodium, which has a low fusing point, we do find a pair of solitary lines about W L. 840.

When you heat platinum wire by a current of electricity, at first though it may be hot to touch, it remains dark. Then, as you increase the current, it gets red and hotter still, and new waves —green—put in an appearance; and finally we get white light. At 550 degrees centigrade the body shows redness. At a white heat we have the whole of the visible spectrum present. Whether all the waves exist at ordinary temperatures in the platinum wire is a matter for future consideration. It is, I think, possible that such may be the case, provided the amplitude be very small indeed. At all events, the molecules of the body on which the source of radiation falls must be in a state ready to vibrate with the higher wave-length. Each wave as it puts in its appearance has a certain amount of energy, and a comparison between the energy of the two waves may be shown by photography as well as by their heating effect. But the heating effect is the true comparative measure of energy if the body on which it falls completely absorbs the radiations. Lamp black, perhaps, is the most perfect absorbent of all radiations, and the energy is shown by the heating effect on it. This heating effect in its turn is converted into an electric current by the use of a thermo-pile. Here is a thermo-pile which is capable of movement by a screw in any required direction, and we will take a very brilliant spectrum and cast it upon its face. It is connected with the galvanometer, and the galvanometer reflects a spot of light on this scale, and when a current passes that spot of light is deflected. You will see whereabouts it is. Now if I move the face of the pile gradually into the yellow I think you will find that it will move slightly up the scale. We will bring it more into the red, and if the galvanometer is in order you will see that it ought to be deflected still more. We have now got it in the infra-red part of the spectrum. The deflection is still greater.

It was by noting the deflections in somewhat this way that Dr. Tyndall was able to construct his spectrum monogram of the electric light, using as his material prism rock salt. The limit of the red is shown by an arrow, on the left is the thermogram of the visible part of the spectrum, and on the right of the invisible part of the spectrum (Fig. 20). Now this thermogram is a puzzle, or rather was a puzzle, in a great many ways. For instance, if you know the wave-length of any two points you may find the theoretical limit of the spectrum by the method which I showed you in my last lecture. Unfortunately it lies well within the heat curve, or rather the effect of heat which is shown in the diagram.

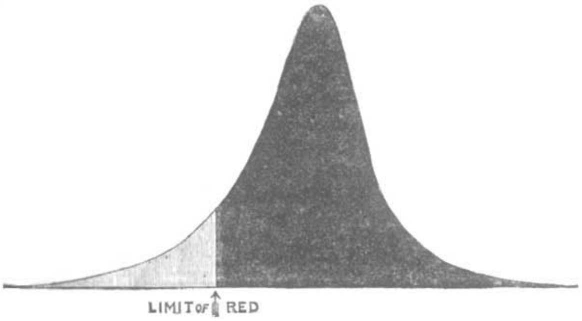

FIG. 20.—Tyndall's thermogram of the spectrum of the electric light.

When working it out in this way it will be found that what I may call the thin tail of the thermogram lies beyond the theoretical limit of the spectrum. But before I go any farther I want to show you a possible cause for this. This rock salt prism has been very finely polished by an optician, and I will mount it in the place of the bi-sulphide of carbon prism which we have so far employed. Now rock salt is supposed to allow the low radiations to pass through much more readily than a glass prism. We will try to get the spectrum tolerably pure. You will see that there is a fairly bright spectrum upon a piece of card.

Now in making observations with rock salt prisms, Col. Festing and myself were rather mortified to find that we got beyond the limits of the spectrum when employing photography.

Our curiosity was therefore raised, and we endeavoured to find out why this was the case. We therefore placed some bichromate of solution of potash in front of the slit of the spectroscope and observed the spectrum. I will repeat the experiment, and you see that all round the spectrum we have a wide spreading yellow halo which is due to the imperfection in the rock salt. The rock salt surfaces are as perfect as grinding can make them, but still there is a certain amount of diffused light which passes irregularly through the prism, and gives us that yellow halo. It is totally different as you will notice when you replace the bi-sulphide prism in position. You get a pure spectrum. You will see that each side the green and the red is tolerably sharp, and when you use a properly adjusted spectroscope the perfections, and for that matter the imperfections, are much more apparent than they are when making a lecture-table experiment. I have shown you this experiment that you may see with what caution measurements taken with rock salt should be received. I may say that we tried not only one prism but three or four, made out of different samples of rock salt, and all gave a like result. The only way we can use a rock salt prism when it is well ground is to allow an excessively narrow beam of light to pass through it. Directly any large surface of the prism (as is the case when a lantern, or condensing lens for condensing the beam upon the slit), is used, the action of diffused light at once renders the results liable to suspicion.

Now I will show you other figures obtained from a thermo-pile when using very delicate apparatus. I wish to show you how the thermo-pile and photography can work hand in hand. We have a thermogram taken with a glass prism, and you will see that it presents some features of similarity—not quite like Tyndall's thermogram. There is a reason for this difference, which is that the one is a thermogram of the positive pole of a powerful electric light, whereas I believe the other was taken with the whole of the radiation coming from both of the poles and from a less powerful electric light. The negative pole of the light we used has been calculated to have approximately a temperature of 3,000°, whilst the positive pole approximately a temperature of about 4,000°. When using a source of one temperature, and that temperature of about 4,000°, you will see that the curve forms a cusp, that is at the place of maximum heating effect it comes very nearly to a point, and I believe that if we obtained a spectrum of a source of heat at a perfectly even temperature we should get that thermogram with an absolutely sharp point. By taking photographs we are able to check the results of the thermo-pile.

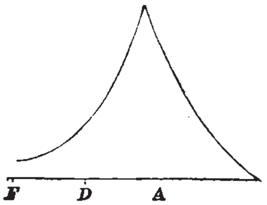

FIG. 21.—Thermogram of the spectrum, the positive pole of the electric light.

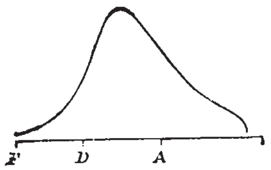

FIG. 22.—Energy curve of the same spectrum as Fig. 21, obtained by means of photography.

Fig. 22 is an energy curve as depicted by a photograph. You see it does not come to nearly such a sharp point as when a thermo-pile is used, and you ask why. The reason is that at that particular part the bromide of silver—blue bromide—does not entirely absorb the radiations, but allows a certain amount to pass through. Nevertheless you will see that there is a striking similarity between the two.

Now I wish to show you how you may combine the thermographs of two or more temperatures. I must, first of all, show you the thermographs of varying temperatures (Fig. 23). We have a temperature of 250°. Next we have a temperature of 500°; next 2,000, next 4,000.

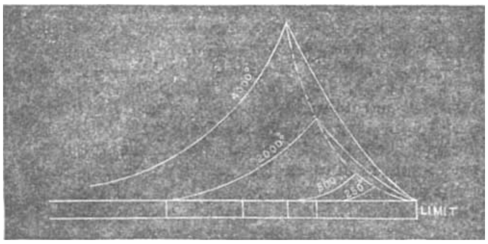

FIG. 23

In diagram (Fig. 24) we have a combination between the thermograms of two temperatures, one of about 2,000°, and the other of about 4,000°. By measuring the height of these curves and taking the mean you get the central curve. You should compare this with Prof. Tyndall's curve. You see it is not very different from the curve taken from the combination of the two curves. My time, however, is drawing to a close, and I am obliged to go but shortly through this part.

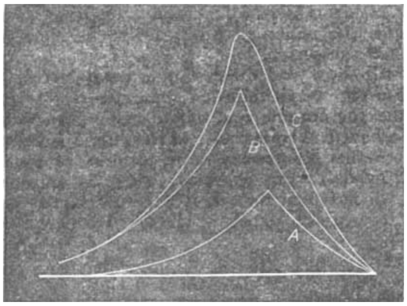

FIG. 24.—Combination thermogram.

In my last lecture I showed you how the diffraction spectrum was spread out in the infra-red in comparison with the prismatic spectrum, and I think that it may interest you here to show you the way in which a thermogram of the solar spectrum is spread out when the prismatic thermograph is altered into a refraction thermograph or thermogram.

In Fig. 26 I give a diagram of a solar prismatic spectral thermogram (Fig. 25) as obtained by Lamarsky spread out into a diffraction curve. You see that instead of the maximum heating effect of the solar spectrum being beyond the red, it lies well between E and D. In other words the maximum energy of the solar spectrum lies in the yellow and not in the ultra red as has usually been considered.

The energy of a wave, or a series of waves, is measured by the square of the amplitude divided by the square of the wave length into a constant. The area of wave section is equal to the amplitude—that is to say the height of the wave multiplied by the length of the wave into a constant. If these waves have equal sectional areas, the energy varies inversely as the fourth power of the wave length. And what I wish to draw your attention to is this—that starting from the theoretical limit of the prismatic spectrum to the maximum heating effect of any continuous spectrum a law seems to hold that the energy of any portion of the spectrum below its point of maximum energy does vary inversely as the fourth power of the wave length.

I am sorry I have not time to go farther into the detail of this, but it has been the result of some considerable calculation, and experiment.

After my last lecture I was asked whether the photograph taken by the kettle in the manner explained was not due to the heat rays. I am afraid my reply was somewhat short as I said, "There are no such things as heat rays." I think that now may be an opportunity in which to express my views on the subject in a less curt manner than that in which I answered my questioner. It is true that we often do hear of dark heat rays and of radiant heat, and the rays which are principally concerned in the latter definition are taken to lie in the infra-red region of the spectrum. I would ask, "Why give them a name to which, it seems to me, exception can be justly taken?" In 1800, Sir William Herschel proved that these dark rays could be refracted and reflected like those rays which, falling on our retina, give us the sensation of colour. Professor Forbes, in his celebrated experiments, proved the same thing; but, in addition, he likewise proved that they could be polarised. I think I have laid before you proofs that these same rays can expend their energy in chemical action causing a disruption of a molecule by their successive impacts. Those rays, by whose agency we see, exercise the same functions as these dark rays. All rays are alike, and whether they cause a rise in temperature, or cause a chemical decomposition of a body, depends solely on the nature of that body on which they fall. The waves, as I have tried to demonstrate, carry energy and nothing else; and they must meet with some obstruction which shall destroy their motion before they can show that they possess energy. The work done by them is manifested by either molecular motion, or atomic motion, or both; the molecular motion of the body showing itself perhaps as heat, and the atomic motion as chemical action. If we must have the word "radiant" tacked on to a definition, (and the word "radiant" is a remnant of the corpuscular theory of heat,) all the wave motion in the ether should be classed under the head of "radiant energy." If a shorter nomenclature is required, let us simply call it "light," including in it the energy carried. Light is an old word understood in one sense by all, and we need only talk of the heating effect of light, and so on. The word "actinism" falls into an equal condemnation. We have unluckily none of our most eminent philosophers who are scientific photographists, if there were I do not believe any would defend the retention of the word "actinic" "or chemical rays" amongst

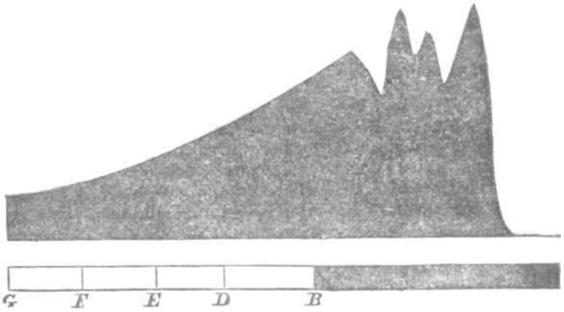

FIG. 25.—Prismatic thermogram of solar spectrum obtained by Lamansky.

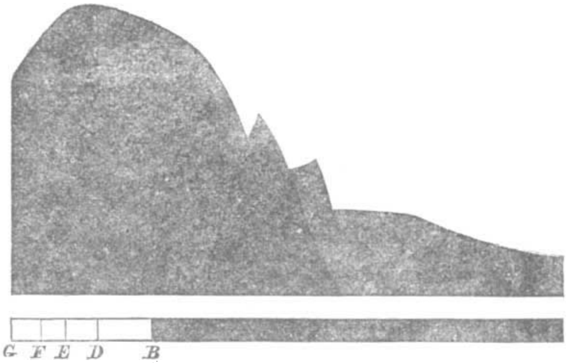

FIG. 26.—Diffraction thermogram from Fig. 25.

our scientific terms. In the expression actinism and radiant heat, the cause has been mixed up with the effect. To be consistent, given one class of bodies the rays falling on it should be called actinic rays; whilst, given another, they should be called heat rays.

In 1840 Dr. F. W. Draper, of New York, clearly pointed out the identity in quality (if I may so call it) of the light, heat, and actinic rays, and that identity, I hold, has been confirmed more than once by recent investigators. I speak, perhaps, somewhat strongly on this point as no one knows better than myself the immeasurable mischief which a wrong definition causes in the progress of a scientific education. Men matured in science can afford to use any definition since they can carefully guard it by mental reservations as to what they really understand by it; but I hold it as a misfortune of no mean order that definitions, which are not so exact as our present state of knowledge can make them, should be given to the uninitiated whose reasoning powers must at the outset be feeble. A definition containing but half a truth must of necessity lead a student of science to a wrong conclusion at some time or another. If our writers of text-books could but be persuaded to write as they believe in this matter, and as some have written (for instance, Clerk Maxwell), we should have fewer mistakes made in explaining the ordinary phenomena met with in daily life.

I think I have now explained what I meant when the answer was given, " There are no such things as heat rays: " a source of energy may be darkly hot as was the kettle, some of the energy radiating from it was expended in heating bodies round it, but that portion which radiated through the holes perforated in the card and which struck the plate was, at all events, partially expended in converting the silver bromide into the sub-bromide.

In the course of these lectures, which I now finish, it has been my endeavour to show you the principles on which experiment in the infra-red region has been carried out, and also to point out the necessity for further work of no light kind in this part of the spectrum. The preceding lectures will also have shown you that work is required to investigate the visible part of the spectrum, and also in the observation of the various phenomena presenting themselves on the solar surface which must of necessity react upon our earth. It has been ignorantly said that the study of solar physics will be exhausted in ten or twelve years, but from what you have heard my colleagues tell you it will surely last our lifetime. If I live till the exhaustion takes place, my allotted threescore and ten years will, I should say, be greatly overstepped. I prophesy, though it can hardly with decency be called a prophecy, that many generations will pass away before all is known of the exact relationship between solar and terrestrial phenomena. What we do know already is hardly the alphabet of the language in which the sun addresses us; and until that alphabet is mastered the whole story that he would tell us must remain undeciphered.

MORPHOLOGY OF THE TEMNOPLEURIDÆ

THE following is an abstract of a communication read before the Linnean Society, Dec. 15, 1881:—The Temnopleuridæ, a sub-family of oligopores, are remarkable for their sutural grooves and depressions at the angles of the plates. The author examined the grooves and depressions or pits in *Salmacis sulcata*, Agass, and found that these last are continued into the test as flask shaped cavities sometimes continuous at their bases which are close to the inside of the test, but do not perforate. This is the case in the median vertical sutures of the interradium and ambulacrum. Between the interradium and the poriferous plates of the ambulacra are numerous pits in vertical series which are the ends of cylinders closed and often curved within. Altogether the undermining is considerable. The grooves over the sutural margins are losses to the thickness of the test. The edges of the contiguous plates are sutured together, by a multitude of knobs and sockets $\frac{1}{300}$ of an inch in diameter visible with a hand lens. In the vertical sutures there is an alternate development of knobs and sockets on each plate corresponding to a similar development on the opposed plates. Between the horizontal plate edges are sutures remarkable in their distinctness and position. The apical edges of the interradial plates have multitudes of sockets and the actinal edges, knobs: whilst the apical edges of the ambulacral plates have knobs and the actinal have sockets. The ambulacra, on their interradial edge have nothing but knobs and the interradial plates corresponding sockets, so that a great series of knobs and socket "dowelling" prevails. *Temnopleurus torematicus*, Agass., gave similar results modified by the great development of the grooves and the young form was shown to differ from the adult, and to have rows of knobs and sockets, and barely penetrating pits. The arrangement in *Salmacis bicolor* and *Amblypneustes ovum* was considered. The pits have an importance for they increase the superficies of the derm and near the peristome, as indicated by Lovén, they contain *Sphæridia.*

The paucity of knowledge respecting the union of the plates of the Echinoidea was noticed and the nature of the suturing of Echinus and *Diadema* was explained, the first resembling part of that of a young *Temnopleurus*, but it was without knobs and sockets. The author concluded by separating the Temnopleuridæ into two divisions, those with pits and those with grooves without pits. The last are the oldest in time and resemble young modern forms which subsequently develop pits. He reduced the number of genera considerably.

P. M. DUNCAN

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

WE are glad to learn that the number of students who have entered the Chemical Laboratory of Firth College, Sheffield, this session, has been so great, that the present accommodation has been quite insufficient. The Council, therefore, decided at their last meeting to erect working benches for sixteen more students. The University of Edinburgh have recently recognised Dr. Carnelly, Professor of Chemistry in Firth College, as a Teacher of Medicine in Sheffield, whose lectures on Chemistry, and course of instruction in Practical Chemistry shall qualify for graduates in Medicine in that University. The lectures on Chemistry and Laboratory Practice at Firth College have also been recognised by the Royal College of Surgeons and the Royal College of Physicians.

SCIENTIFIC SERIALS

American Journal of Science, October, 1881.—Cause of the arid climate of the western portion of the United States, by C. E. Dutton.—Embryonic forms of trilobites from the primordial rocks of Troy, N.Y., by S. W. Ford.—Observations of comet *b*, 1881, by E. S. Holden.—Thickness of the ice sheet at any latitude, by W. J. McGee.—Notes on earthquakes, by C. G. Rockwood. Marine fauna occupying the outer banks off the southern coast of New England, by A. E. Verrill.—Note on the tail of comet *b* 1881, by L. Boss.—Geological relations of the limestone belts of Westchester Co. New York, by J. D. Dana.

November, 1881.—Jurassic birds and their allies, by O. C. Marsh.—The remarkable aurora of September 12–13, 1881, by J. M. Schæberle.—The stereoscope and vision by optic divergence, by W. L. Stevens.—The electrical resistance and the coefficient of expansion of incandescent platinum, by E. L. Nichols.—Local subsidence produced by an ice-sheet, by W. J. McGee.—Notes on the Laramie group of Southern New Mexico, by J. J. Stevenson.—Polariscopic observations of comet *c* 1881, by A. W. Wright.—The relative accuracy of different methods of determining the solar parallax, by W. Harkness.—The nature of Cyathophycus, by C. D. Walcott.

Journal of the Franklin Institute, December, 1881.—Report of the committee on the precautions to be taken to obviate the dangers that may arise from electric lighting.—Report of committee on fire-escapes and elevators.—Chemical methods for analysing rail steel, by M. Troilius.—Notes on the properties of dynamo-electric machines, by E. Thomson.—Blast-furnace hearths and linings, by J. Birkinbine.—Sand-filtration at Berlin, by W. R. Nichols.—Report of committee on Griscom's electric motor.—Weighing the sun by a soap-bubble, by P. E. Chase.

Bulletin de l'Académie Royale des Sciences de Belgique, Nos. 9 and 10.—*Apropos* of determination of latitude, by M. Folie.—On the origin of Devonian limestones of Belgium, by M. Dupont.—Application of accidental images (second note), by M. Plateau.—A means of measuring the flexure of telescopes, by M. Rouzean.—On the micaceous substance of veins of Nil St. Vincent, by M. Renard.—Reports, &c.

Archives des Sciences Physiques et Naturelles, December, 1881.—International Geological Congress of Bologna, September and